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Energy consumption patterns by local residents in four nature reserves in the subtropical broadleaved forest zone of China

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ABSTRACT

Collection of fuelwood by local residents in or around nature reserves of China has caused problems such as disturbance of habitat for wildlife and deforestation. Thus, it is important to study the energy consumption patterns by those local residents live in or around nature reserves to find solutions to reduce the amount of fuelwood consumption. We chose four nature reserves: Longxi-Hongkou National Nature Reserve, Sichuan Province, Taohongling National Nature Reserve, Jiangxi Province, Qingmuchuan Nature Reserve, Shaanxi Province, and Laoxiancheng Nature Reserve, Shaanxi Province in the subtropical zone of China to study this problem. We found no significant difference of total energy consumption per household per year in the four nature reserves, which was about 2 ton of standard coal per year. But the energy consumption patterns in different reserves were different. People who live in deep mountains more relied on collecting fuelwoods from surrounding forests whereas those live in areas with relatively developed economy and better transportation condition consumed more coals, liquidinized petroleum gas and electricity. Such a pattern also reflects the changing energy spectrum during the process of modernization in China. We concluded that economic status of household and the transportation condition are two important factors affecting the energy consumption patterns in households in the nature reserves in China, which reflect the general energy consumption in rural China.

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1. Introduction

In developing countries, biomass is the most important energy source, especially fuelwood [1] and crop residuals [2], where biomass provides roughly 30% of the total energy supply and woods account for more than half of the biomass [3]. In some

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countries such as Nepal, Bangladesh, Ethiopia, Burkina Faso, and even oil-rich Nigeria, fuelwood accounts for more than 75% of the energy used [2–5]. Demand for fuelwood has linked to deforestation [6–11], total energy demand [5,6,10], agricultural productivity [5–10], loss of plant and wildlife habitat [5,7,9,11–14], environmental collapse associated with droughts, floods, or other extreme climatic events [5], and increased labor costs for fuelwood collection [5,7,8].

With a total area of 9.60 million km^2 and a population of 1.3 billion people, China is one of the largest developing countries in the world and a country with extensive rural areas where consumption of biomass such as fuelwood is large. It was reported 61% of the energy used by rural households in China are biomass, in the year 2001 along the country consumed over 190 million m^3 of fuelwoods [7]. In some places, fuelwood collection has caused deforestation, consequently it led to serious soil erosion, floods and sand storms [15]. In order to reverse this trend, reforestation programs have been initiated since the beginning of 1980s. For example, two important programs have been implemented in China since late 1990s, one is Natural Forest Protection Program; another is the Green for Grain Program (Conversion of Farmland to Forest Program [7,15]). During the same time, many nature reserves have also been established in China. The development of modern nature reserves in China began in the 1950s but escalates in recent decades [16]. Number of nature reserves increased from 34 reserves in 1978–1999 reserves by the end of 2003, area of those nature reserves accounted for 17.73% of the land territory of country. Among these nature reserves, the nature reserves for protecting forest ecosystems account for about 66% in area [16].

Implementation of the national wide forest protection programs has resulted in improvements of the forest resources. However, such a success has not significantly alleviated China's forest resource crisis that was characterized by a high demand for wood products and environmental services. Fragile and degraded ecosystems and wildlife habitats are in need of rehabilitation and protection through appropriate forest management practices in the country [17]. Most of the nature reserves in China are divided into three functional zones as that recommended by Man and Biosphere (MAB): a core zone, a buffer zone, and an experimental zone [18]. Core zone in a nature reserve is strictly protected; normally no people live in core zone, but there are some people still live in buffer zone and experimental zone of nature reserves. Usually, the people living near or within the nature reserve live on the forest. Primary energy those people use is biomass, especially fuelwoods. In some forest type nature reserves, the behaviors of human, including collection of fuelwood, have caused the degradation of the habitat of wildlife, such as which happened in the Wolong nature reserve [13,19]. Thus, it is important to study the pattern of energy consumption of local people who live near or within nature reserves and find what factors affect their energy consumption patterns. However, such researches are absent and most of the nature reserve managements do not realize this problem. Therefore, we carried out a study on the fuel consumption pattern in four selected nature reserves in broadleaved forested area in subtropical zone of China. We particularly interested in following questions: whether there are statistically significant difference among total energy consumption and quantity of fuelwood consumed in different nature reserves in subtropical China? Are energy consumption and composition of energy consumed correlated with economic status, transportation condition, household size? Does condition of transportation conditions affect energy consumption and composition of energy consumed in villages? We used computer software SPSS to assess significance of the differences and correlation. Finally, we discussed the implication of results to fuelwood use and sustainable development in rural area near the nature reserves.

2. Study areas

We carried out the survey in four nature reserves in the subtropical forest zone: Taohongling National Nature Reserve, Jiangxi Province (29°42′–29°53′ N, 116°32′–116°43′ E), Longxi-Hongkou National Nature Reserve (31°04′–31°22′ N, 103°32′–103°43′ E), Sichuan Province, Qingmuchuan Nature Reserve, Shaanxi Province (32°50′–32°56′ N, 105°28′–105°40′ E), and Laoxiancheng National Nature Reserve, Shaanxi Province (33°43′–33°57′ N, 107°40′–107°49′ E) in China from 2002 to 2005 (Fig. 1).

Taohongling National Nature Reserve was established in 1981. The reserve is established for protecting southern China subspecies of wild sika deer (*Cervus nippon kopschi*), which is a critically endangered wild animal in China. Local flora is complex and the vegetation is dominated by evergreen broadleaved forest. Because of the over logging and frequently wildfire, original vegetation was destroyed in the history. Now shrubs developed in most of the areas in the reserve [20].

Longxi-Hongkou national reserve was established in 1997 for protecting forest ecosystem and wild animal species, such as giant panda (*Ailurojpoda melanoleuca*), golden-haired monkey (*Rhinopithecus roxellanea*), takin (*Budorcas taxicolor*) and dove tree (*Davidia involucrata*). This nature reserve links the giant panda populations in the Mishan Mountains and the Qionglai Mountains; thus it serves as an important natural corridor for the giant panda and other wild animals in the region.

Qingmuchuan Nature Reserve was established in 2002 for protecting giant panda, golden-haired monkey and its associated fauna. Biogeographically, the reserve lies between the Palaearctic Realm and Oriental Realm, where subtropical evergreen broadleaved forest and subtropical deciduous forest develop due to typical northern subtropical climate: rich precipitation and solar radiation. There are three major forest types: subtropical mixed deciduous and evergreen broadleaved forest, sub-alpine cool temperature deciduous broadleaved forest and evergreen coniferous forest. The fauna has animal species from warm temperate zone to subtropical zone, but the species of the Oriental Realm: takin, golden-haired monkey, macaque (*Macaca mulatta*), musk deer (*Moschus berezovskii*), golden pheasants (*Chrysolophus pictus*), golden eagle (*Aquila chrysaetos*), and the giant panda are found here [21].

Laoxiancheng nature reserve was established in 1993, the reserve is located in the center of the Qinling Mountains. There are

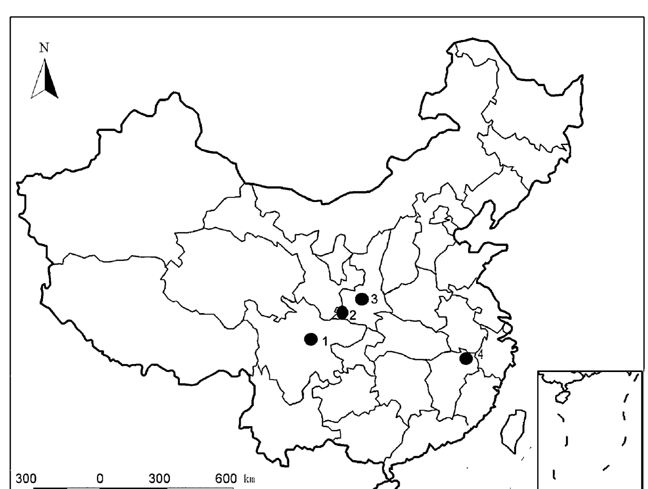


Fig. 1. Locations of the four nature reserves in China. 1: Longxi-Hongkou National Nature Reserve, Sichuan Province; 2: Laoxiancheng National Nature Reserve, Shaanxi Province; 3: Qingmuchuan Nature Reserve, Shaanxi Province; 4: Taohongling National Nature Reserve, Jiangxi Province.

Table 1
Comparison of climate, transportation conditions, economic condition and sources of energy in Longxi-Hongkou, Taohongling,Laoxiancheng, and Qingmuchuan nature reserves.

	Longxi-Hongkou	Taohongling	Qingmuchuan	Laoxiancheng
Climate	Humid monsoon subtropical climate Average annual temperature is 15.2 °C. Annual frost-free period is 243 days	Warm and humid monsoon subtropical climate. Average annual temperature is 16.5 °C Annual frost-free period is 247 days	Cool subtropical climate Average annual temperature is 12.9 °C. Annual frost-free period is 247 days	Monsoon mountain climate Average annual temperature is 8.4 °C Annual frost-free period is 150 days
Transportation[a] condition	Near a country highway	Near a country highway	Far away from township road, the local people have to walk for two hours to go to the town where has a bus station	Only a countryside trail leads to village, local people have to walk for five hours to go to the town where has a bus station
Source of income	Ecotourism and agriculture	Agriculture and wok in cities	Agriculture	Agriculture and ecotourism
Source of energy	Fuelwood, bottled LPG, coal, and electricity	Fuelwood, bottled LPG, coal, electricity and crop	Fuelwood, bottled LPG, coal, and electricity	Fuelwood
Population	No people live inside the nature reserve, but two towns lie in the adjacent-protection zone of reserve, and the human density of the adjacent-protection zone was 0.975 capita/hm^2	Human density was 3.70 capita/hm^2 in the experimental zone of reserve	More than one village in the experimental zone of the reserve, the human density was 0.11 capita/hm^2	One village in the experimental zone of the reserve, human density was 0.02 capita/hm^2

[a] There are five types of roads in China according to the Regulations on Management of Highways in the People's Republic of China: national highway, provincial highway, county road, township road and commute road according to the management authorities. The most useful roads are country road and town road in Chinese rural areas and there are bus stops on country road normally.

also three major forest types in the reserve, which are deciduous broadleaved forest, mixed deciduous broadleaved forest and coniferous forest. The reserve supports many kinds of vertebrates, especially some rare and specific species: giant panda, takin, golden-haired monkey, leopard (*Panthera pardus*), musk deer, golden pheasants, golden eagle, and blood pheasants (*Ithaginis cruentus*). Noticeably, density of giant panda in the reserve was extremely high according to recent national wide giant panda survey [22].

Comparisons of climate, transportation, economic status and energy source and human population density are given in Table 1.

3. Methods

In this study, households in the nature reserves were chosen as research units. We investigated six villages and 90 households in Longxi-Hongkou nature reserve, 28 households in Laoxiancheng nature reserve (there is only one village in the reserve), four villages and 60 households in Qingmuchuan nature reserve and four villages and 60 households in Taohongling nature reserve. All households were stratified sampling selected according to the economic status of each household.

The study was carried out from July 2003 to December 2004, we recorded the number of people in each household, the economic status of household, and annual energy consumption. The energy sources include fuelwood, bottled liquefied petroleum gas (LPG), coal and electricity. We used the same standard to record of the data of the economic status of household and the traffic condition of village. We used the Participatory Rural Appraisal (PRA) tool to survey the quantity energy consumed in household. PRA encourages participation of local people, which is now widely advocated and documented as a tool in development and conservation [23].

Altogether, 238 households were sampled. Because some households gave incomplete information; data of those families were deleted later in analyses. Remaining valid number of households was 220 altogether. Household characteristics, such as family size, economic status and transportation conditions, in the four nature reserves were different (Table 2).

We studied the type of each energy source consumed and the total energy consumption by each household in the four nature reserves and the factors that may affect the energy consumption among four nature reserves, such as family size, economic status of household, and transportation condition of village.

We used SPSS 11.0 to analyze the data. One-way ANOVA was used to test the difference of total energy consumption and the quantity of fuelwood consumed in four nature reserves. Spearman's correlation was used to test the correlation between economic status, transportation condition, household size, consumption of energy and composition of energy consumed in the households. Kruskal–Wallis *H* was used to test the difference of energy structure of different village in Longxi-Hongkou nature reserves and Qingmuchuan nature reserves on the condition of different transportation conditions on energy consumption.

4. Results

4.1. Energy consumption patterns

Four types of energy were used by local people, but the quantities of each type of energy consumed were different in the four nature reserves (Table 3). Fuelwood was the most important energy in four nature reserves. Among these nature reserves, the households in Laoxiancheng nature reserve consumed more fuelwood than the other three nature reserves, followed by the Qingmuchuan nature reserve, and the residents in Longxi-Hongkou nature reserve consumed the least fuelwoods. Of the energy consumed in the Longxi-Hongkou nature reserve, 57% were fuelwoods, 32% were coals, 7% were electricity and only about 4% were the LPG. In Taohongling nature reserve, coal and electricity made up similar ratios of the total energy consumption. Qingmuchuan was a special case; its local residents entirely depended on the fuelwood as fuel energy, while the other three sources of energy made up only 7.9% of total energy consumption. Although the consumption of different energy source per household was different, the total energy consumed per household was no significantly different among these nature reserves (Table 3, Fig. 2).

There was no significant difference among the total energy consumption per household in the four nature reserves ($F = 0.898$; $P = 0.443 > 0.05$; ANOVA).

Table 2
Family sizes, economic status of household and transportation conditions in the Taohongling, Longxi-Hongkou, Qingmuchuan and Laoxiancheng nature reserves.

Nature reserve	Village	Family size[a] (mean ± SD)	Economic status[b] (mean ± SD)	Transportation condition[c]	N[d]
Taohongling	Taohong	2.77 ± 0.23	3.08 ± 0.21	2	13
	Datang	3.00 ± 0.33	3.36 ± 0.13	2	14
	Hewu	2.62 ± 0.27	3.15 ± 0.25	2	13
	Jianshan	3.64 ± 0.29	3.50 ± 0.14	2	14
Longxi-Hongkou	Shenxigou	2.91 ± 0.56	2.09 ± 0.31	1	11
	Bayi	3.93 ± 0.37	3.64 ± 0.25	3	14
	Nanyue	3.93 ± 0.28	2.53 ± 0.27	2	15
	Hongse	3.87 ± 0.24	2.53 ± 0.22	1	15
	Hongkou	3.20 ± 0.37	2.64 ± 0.20	1	14
	Dashuigou	4.00 ± 0.31	3.50 ± 0.17	4	14
Qingmuchuan	Fenliba	4.04 ± 0.31	4.56 ± 0.23	4	25
	Changshaba	3.50 ± 0.40	4.10 ± 0.43	3	10
	Nanba	3.42 ± 0.34	3.33 ± 0.31	2	12
	Qingmuchuan	4.15 ± 0.44	2.62 ± 0.21	1	13
Laoxiancheng	Laoxiancheng	3.48 ± 0.27	3.04 ± 0.20	4	23

[a] Families size do not include those people who were not live in the family during the last 10 months before the investigation. Many countryside people moved to city and the coastal area for work in China, those people are migratory workers.
[b] We divided the economic status into seven types. If the total annual income was equal to over 20,000 Yuan RMB, we recorded it as "1"; if the total annual income was between 10,000 and 20,000 Yuan RMB, we recorded it as "2"; if the total annual income was between 5000 and 10,000 Yuan RMB, we recorded it as "3"; if the total annual income was between 3000 and 5000 Yuan RMB, we recorded it as "4"; if the total annual income was between 1000 and 3000 Yuan RMB, we recorded it as "5"; if the total annual income was under 1000 Yuan RMB, we recorded it as "6".
[c] Transportation conditions are ranked according to the distance between the villages and the county road. If the distance was less than 500 m, we recorded the transportation condition as "1"; if the distance was between 500 and 2000 m, we recorded it as "2"; if the distance was between 2000 and 8000 m, we recorded it as "3"; if the distance was more than 8000 m, we recorded it as "4".
[d] Sample size.

Table 3
Quantity of energy consumption per household per year in the Longxi-Hongkou, Taohongling, Qingmuchuan, and Laoxiancheng nature reserves.

Energy source	Longxi-Hongkou	Taohongling	Qingmuchuan	Laoxiancheng	F-value	P	Method
Fuelwood (kg)	2036 ± 224	2886 ± 259	4602 ± 491	4935 ± 405	10.63	<0.05	ANOVA
Coal (kg)	1043 ± 194	54 ± 26	77 ± 37	0.00		<0.05	K–W test
Electricity(kW/h)	708 ± 119	300 ± 35	350 ± 129	0.00		<0.05	K–W test
LPG (bottles)	2.96 ± .68	1.28 ± .22	.92 ± .10	0.00		<0.05	K–W test
Crop residuals (kg)	0.00	780 ± 99	0.00	0.00			

4.2. Correlation test

Correlations between household size and total energy consumption per household were not significant in those nature reserves. Correlation between the economic status of household and total energy consumption in household was also not significant (Table 5). The result of correlations between household size, economic status and the total fuelwood consumption in each household were similar to that of total energy consumption (Table 6).

However, energy consumption structures in reserves with different traffic condition were significant different except the electricity consumption in Longxi-Hongkou nature reserve (Table 7). The better the traffic condition, the higher the ratio of LPG and coal-balls consumed. Similarly, the economic status of household also influenced the energy consumption. Correlation between the economic status and energy structure was significant except the ratio of electricity consumption in Longxi-Hongkou nature reserve (Table 8). Consumption of electricity was not

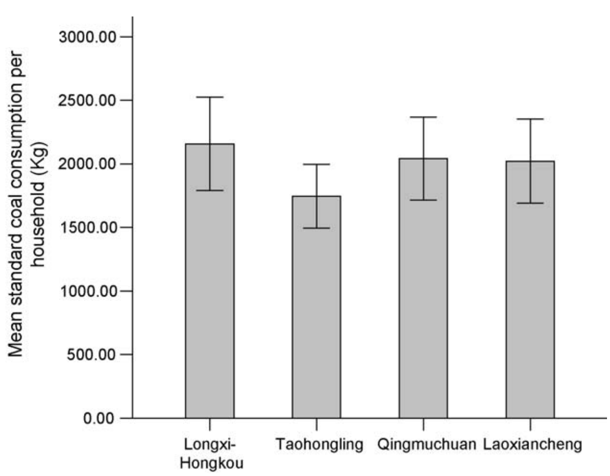


Fig. 2. Total energy consumed per household in standard coal in the Longxi-Hongkou, Laoxiancheng, Qingmuchuan, and Taohongling nature reserves (total energy consumptions were converted to standard coal using the conversion standards in Table 4). The bar indicates 1 SD.

Table 4
Energy conversion factors.

Energy type	Equivalents		
	Unit	10^7 J	kg of standard coal equivalent
Standard coal	kg	2.93	1.00
Fuelwood	kg	1.8	0.61
LPG	One bottle (15 kg)	75	25.60
Crop straw	kg	1.4	0.48
Coal-ball	One ball	2.0	0.68
Electricity	KWh	0.36	0.12

Table 5
Pearson Correlations between household size, economic status and total energy consumption per household.

	Longxi-Hongkou	Taohongling	Qingmuchuan	Laoxiancheng
Household size	$R=0.089$; $P=0.453>0.05$	$R=0.053$; $P=0.703>0.05$	$R=0$; $P=0.997>0.05$	$R=0.214$; $P=0.0326>0.01$
Economic status	$R=-0.165$; $P=0.135>0.05$	$R=-0.183$; $P=0.185>0.05$	$R=0.50$ $P=0.704>0.05$	$R=-0.252$; $P=0.246>0.05$

Table 6
Pearson Correlations between household size, economic status and the total fuelwood consumption per household.

	Longxi-Hongkou	Taohongling	Qingmuchuan	Laoxiancheng
Household size	$R=0.135$; $P=0.253>0.05$	$R=0.112$; $P=0.420>0.05$	$R=0$; $P=0.915>0.05$	–
Economic status	$R=0.520$; $P<0.05$	$R=-0.128$; $P=0.358>0.05$	$R=0.194$; $P=0.138>0.05$	–

Table 7
Tests of traffic conditions of household on the energy source consumption per household[a].

	Energy source used	Kruskal–Wallis test
Longxi-Hongkou	Fuelwood	$P<0.01$
	LPG	$P<0.01$
	Coal-balls	$P<0.01$
	Electricity	$P>0.01$
Qingmuchuan	Fuelwood	$P<0.01$
	LPG	$P<0.01$
	Coal-balls	$P<0.01$
	Electricity	$P<0.01$

[a] Grouping variable: traffic condition.

Table 8
Pearson Correlations between economic status and energy structure.

Nature reserve	Energy source	Correlation
Longxi-Hongkou	Fuelwood*	$R=0.625$; $P<0.01$
	LPG*	$R=-0.503$; $P<0.01$
	Coal-balls*	$R=-0.629$; $P<0.01$
	Electricity	$R=-0.005$; $P>0.05$
Qingmuchuan	Fuelwood*	$R=0.378$; $P=0.003$
	LPG*	$R=-0.308$; $P=0.017$
	Coal-balls*	$R=-0.322$; $P=0.012$
	Electricity*	$R=-0.483$; $P<0.01$

* Correlation was significant at the 0.01 level (2-tailed).

significant different among villages in Longxi-Hongkou nature reserve ($F = 1.716$, $P = 0.131 > 0.05$; ANVOA).

5. Discussion

Since the 1973 Gulf War and an impending "fuelwood crisis" dominated the forestry development agenda in the 1980s, consumption of fuelwood for domestic energy in developing countries has been the cause of concern [6]. Fuelwood use and scarcity reflect complex and variable interactions between local production systems and the environmental resources on which they are based [5]. According to researches on this issue, it seems that there is no crisis of fuelwood in the world yet; however, it indeed is a problem in some parts of the world such as parts of Africa, Asia, and Latin America [3,4]. In China, the energy is also a problem, and the ecological problems caused by the fuelwood collection are even worse [7]. Ericsson and Nilsson emphasized using biomass as alternative source of energy in Europe [24]. China is different from Europe, most natures and artificial forests are still in the initial stage of recovering and the main aim of nature reserve is to protect endangered species and its habitats.

5.1. Energy consumption

Our study shed some light on the energy consumption pattern in the subtropical zone in China. When there are other substitute energy sources, local people would choose substitute energy source such as those live in Longxi-Hongkou nature reserve. Fuelwood is still an important source of energy for the residents in the Longxi-Hongkou nature reserve, but the ratio of fuelwood in the total energy was low compared to those in other three nature reserves, local residents in the Longxi-Hongkou nature reserve use coal, LPG and electricity. In the Taohongling nature reserve, the coal-balls and the electricity consumption made up similar ratios in the total energy consumption, however, the fuelwood was also the primary source of energy. Because the reserve is located in agricultural area where the primary crops are cotton and rice, crop residuals are also an important fuel there and most people burn the straw and cotton residuals as fuel after harvest season. Qingmuchuan nature reserve is a special example, local residents in the reserve almost entirely depended on fuelwood collected from the forest as energy source, other three sources of energy only made up a little percentages of all energy consumption in the reserve. In Laoxiancheng nature reserve, because the village is isolated from outside world, the local people entirely depend on the wood as fuel. Due to their inefficient stoves and longer heating season, the total annual energy consumption per household in reserve was astonishingly higher than that in the towns and cities in the province [25].

5.2. Energy consumption pattern

The four nature reserves in this study represent four types of energy consumption patterns in the subtropical broadleaved forest zone in China. In a reserve in agricultural area, like the Taohongling nature reserve, the local people use crop residuals to make biomass gas; thus to reduce the fuelwood collection pressure on forest. When the traffic condition is good, such as the Longxi-Hongkou nature reserve, the local people could develop their economy quickly and could offer commercial fuels, such as LPG, coal-balls and electricity to replace the fuelwood, thus also reduce pressure on natural forests. For the remote nature reserves, such as Laoxiancheng nature reserve, the transportation and economic condition restrict the energy choice of local residents and the main source of energy is fuelwood collected from the surrounding forests. Fortunately, the human population in the Laoxiancheng nature reserve is small, only 35 households and 155 peoples live in the reserve. People are moving out from the reserve, the number of people and households were decreasing every year. The pressure of local people on the nature reserve is diminishing, however, in recent years, ecotourism is booming in the reserve, more and more visitors from the cities visit the reserve. The incoming visitors put on pressure on fuelwood consumption in the reserve [21].

For seek of reserve management, primary work of these nature reserves that like the Laoxiancheng nature reserve is to control growth of human population and to increase the efficiency of the energy use, such as use energy-saving-stove which burns fuel more efficiently and give up traditional stoves. Qingmuchuan nature reserve was established six years ago, it represents a type of developing nature reserves. In order to reduce the pressure on forest, the reserve should follow the example of Longxi-Hongkou nature reserve to develop local ecotourism or decrease its population size as in the Laoxiancheng nature reserve. In a word, controlling the population growth around or within the nature reserves and increasing the efficiency of energy use are two important measures for nature reserve management, thus nearly 2000 nature reserves in China would make greater contribution to reduced carbon emission by reduced energy consumption and increase carbon fixation by reforestation.

5.3. Factors affecting the patterns for energy consumption

Variations in energy consumption patterns are attributable to a number of reasons, but mainly to policy discrimination because of the inequities in fuel and equipment availability among income groups [5,26], income level [1,5,11,27], improvement in energy efficiency, environmental considerations [11] and socio-cultural conditions [11]. In our study, the different patterns of energy consumption among the four nature reserves may attribute to traffic condition of villages and economic status of household. When transportation condition was not good, it was difficult for the local people to transport coal-balls and LPG to their villages; on the other hand, commercial fuel was beyond the reach if the families are poor. Fuelwood usage was greater for the low-income groups than for richer householders. The poor families often had few alternatives to fuelwood use to meet their basic subsistence needs. It is clearly demonstrated that traffic condition and economic status affect the pattern of energy consumption by villagers in Qingmuchuan nature reserve. However, the result was different in Longxi-Hongkou nature reserve where the electricity consumption has no significant difference even under the different economic status. Some researches found the availability of commercial fuels could affect the consumption of commercial fuels [28]. All villages in Longxi-Hongkou nature reserve have electricity, but only several villages in Qingmuchuan nature reserve have electricity. Rural people use electricity only for lighting and TV not for heating or cooking; thus, there is no significant difference of electricity consumed in household [1].

Climate is known to be an important factor affecting energy consumption patterns [29]. Usually the people in the warm area use less energy than the people live in the cold area. Total energy consumption per household in the four nature reserves has no significant difference because they all located in the subtropical zone. However, there were some differences, local residents in Taohongling nature reserve consumed the least energy because it was warmer than the other three nature reserves, and residents in Taohongling nature reserve consumed less energy in winter for heating.

However, household size, the economic status of household, and the patterns of energy consumption had little influence over the total energy consumptions per household, which confirms the conclusion of Liu et al. [30].

5.4. Energy consumption and conservation

By the end of 2003, there were 1017 forest nature reserves in China, covered an area of 296,911 km^2 [16]. In most of forest nature reserves, fuelwood is the most important source of energy for local residents. Logging tree as fuelwood affects forest regeneration, because people collect young trees as fuelwood most of time. For example, in Laoxiancheng nature reserve, the nature reserve management prohibits local people to collect the trees with the diameters larger than 10 cm, but there is no limitation about the quantity of small woods collected by local residents. In most forest nature reserves of China, the situation is similar. Ecological environment would be worse if the population density was higher. It is the time for nature reserve management to find the suitable measures to decrease the pressure on the recovering forests, to find a sustainable way to develop local economy, to encourage the local people use more commercial fuels, such LPG and electricity to decrease the consumption of fuelwood, and to use efficient stoves to save energy. For the remote nature reserves, it is more important to improve the local education level and to encourage the young people to work outside the nature reserves.

6. Conclusion

Co-management of forests involving local people and management authorities, and restoration of their rights may help to resolve conflicts related to resource use and lead to a better management of natural resources [31]. In our study, two important factors affect the patterns of energy consumption in a household: economic status of the household and transportation condition of nature reserves. Some measures about the patterns of energy consumption should be considered according to different situation to decrease the pressure of nature caused by the fuelwood collection. Manager of nature reserves in developing countries should find a proper way to solve fuelwood problem by changing energy consuming pattern and improving the energy efficiency.

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